Rulison Site

Presentation to

Colorado Oil and Gas Conservation Commission

October 2, 2007

Introductions

DOE Office of Legacy Management

Tom Pauling, Environment Team Lead

Jack Craig, Project Manager

S.M. Stoller Corporation

Rick Hutton, Project Manager

Rex Hodges, Hydrogeologist

Judy Miller, Public Affairs

Desert Research Institute

Jenny Chapman, Associate Research Hydrogeologist

DOE Office of Legacy Management

- Mission
  - Protect human health and the environment through effective and efficient long-term surveillance and maintenance

Presentation Outline

- Provide history and background of site – *Jack Craig*
- Describe monitoring activities – *Tom Pauling*
- Discuss recent modeling report – *Tom Pauling*

Offsite Nuclear Tests Overview

- Offsites – sites where underground nuclear tests and experiments were performed outside of the Nevada Test Site.
- Reasons for these tests:
  - Weapons related
  - Vela Uniform Program: detection and monitoring purposes
  - Plowshare Program: development of nuclear devices for peaceful applications

Offsites Nuclear Tests Overview

Nuclear testing activities conducted in Alaska, Colorado, Mississippi, New Mexico, and Nevada

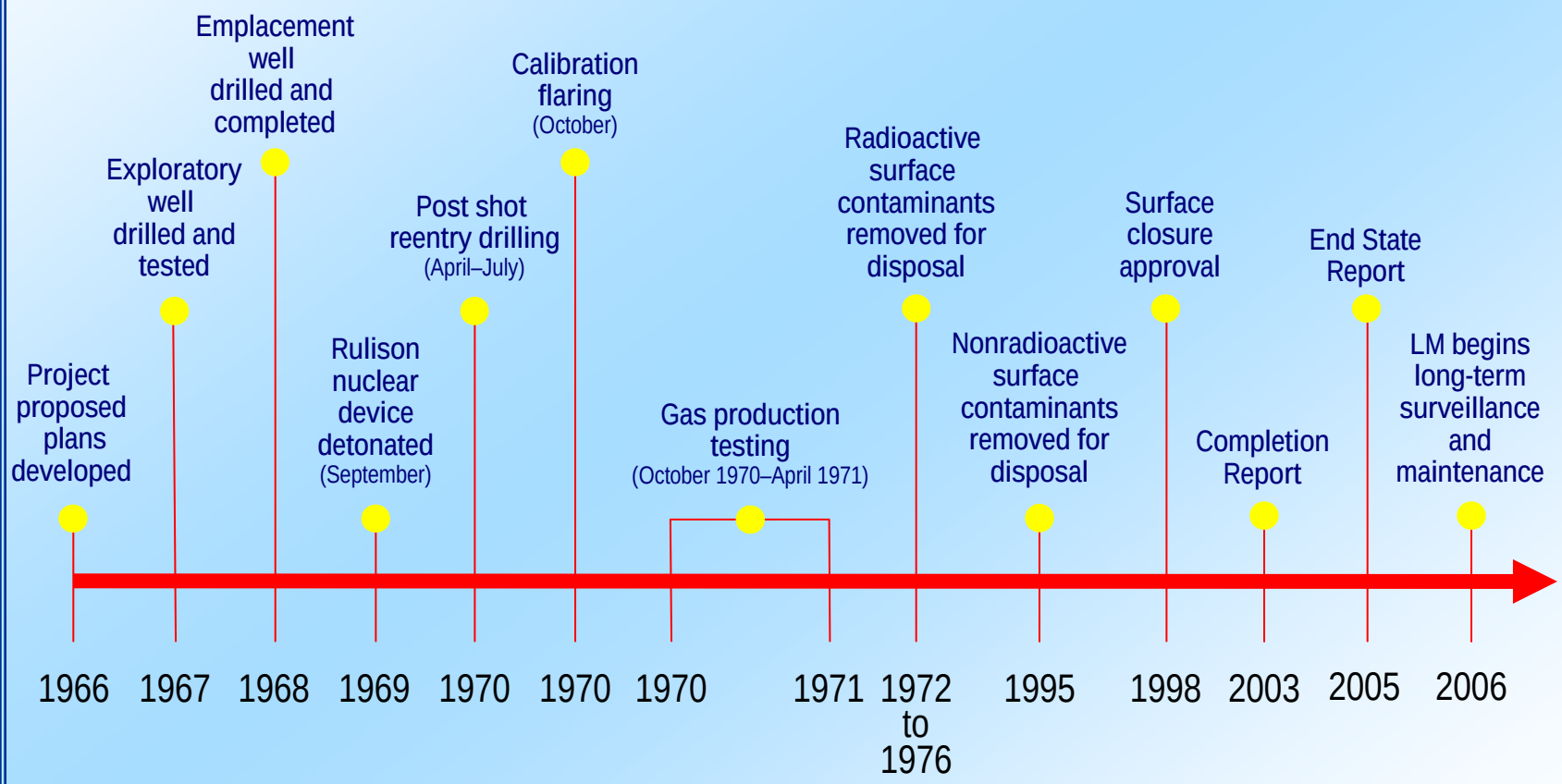
Plowshare Program

- Using nuclear explosives for industrial applications
- Began in 1958 and continued through 1975
- Between December 1961 and May 1973, 27 plowshare nuclear explosive tests (35 individual detonations) were conducted
- Large-scale excavation and quarrying
- Underground engineering
- Stimulation of natural gas production

Rulison Site

- Objective – a joint government industry gas stimulation experiment to investigate the feasibility of using nuclear explosives to stimulate a low-permeability gas field
  - September 10, 1969
  - Yield: 40 kilotons
  - Depth: 8,425 feet
  - Geology: interbedded sandstones and shales

Timeline of Major Events

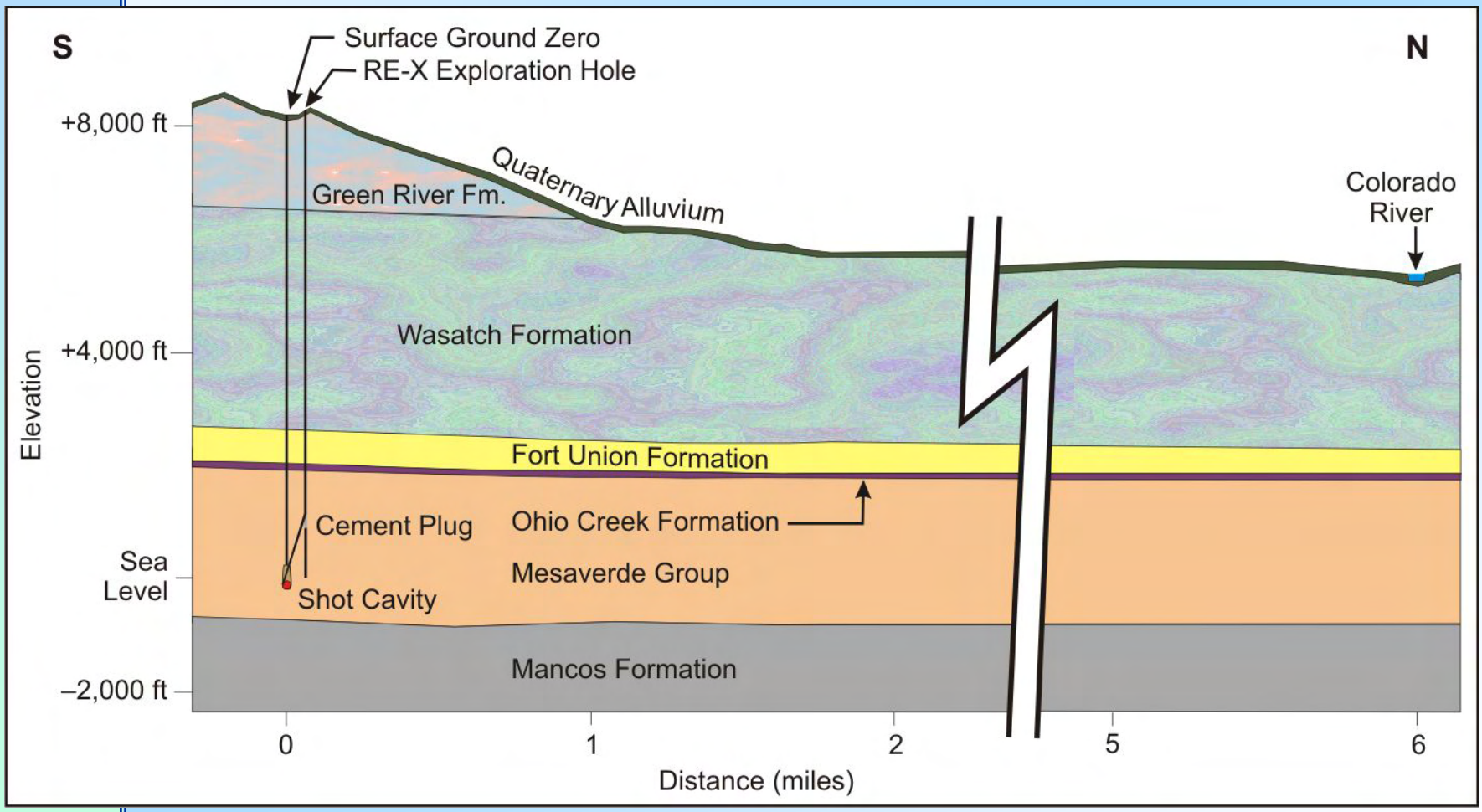


Rulison Site

1969

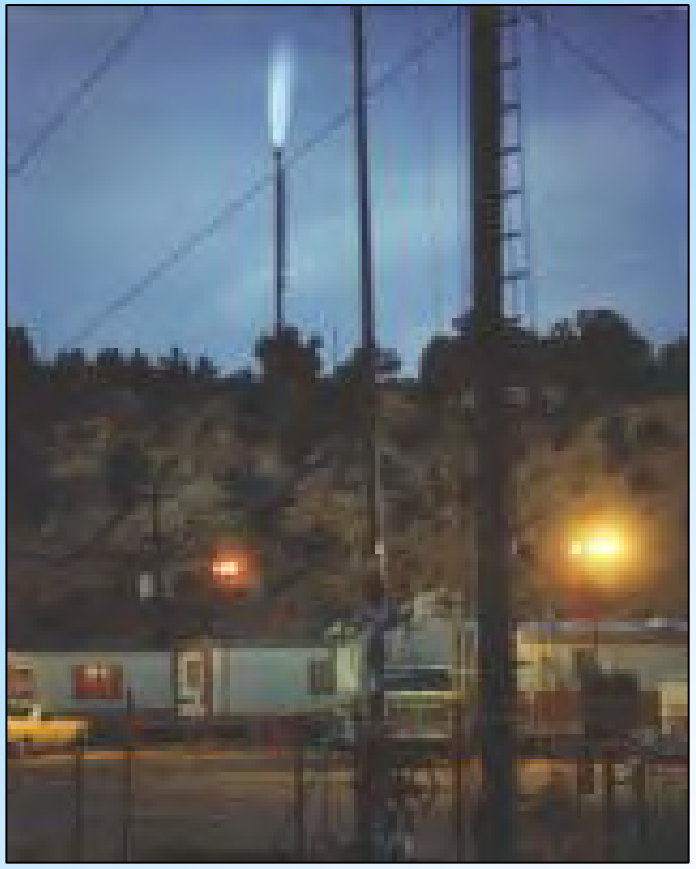
2007

Rulison Site



Production Testing

- 455 million cubic feet of gas was produced (and flared) during 4 tests (110 days) on the reentry well to the chimney
- The produced gas contained radionuclides present in the gas phase (tritium, krypton-85, carbon-14)
- Most of the krypton-85 and carbon-14 created by the detonation were removed during the production testing
- A significant amount of tritium was not removed during the tests and remains in the detonation zone (present in liquid water and water vapor)
- Other radionuclides remain in the nuclear cavity bound in solid or liquid



Flaring

What is Tritium?

- Tritium is a radioactive form of hydrogen
  - Half-life of 12.32 years
  - Half decays to stable helium-3 every 12.32 years
- Naturally produced in upper atmosphere by cosmic rays, which interact with nitrogen and oxygen (natural level is 3 to 15 picocuries per liter)
- Significant quantities released to the atmosphere by above-ground weapons testing (U.S. and Russia)
- The EPA limit for tritium in drinking water is 20,000 picocuries per liter

Monitoring: Potential Pathways

In the past:

- Flaring of natural gas from the Rulison nuclear chimney released radionuclides that created an atmospheric exposure pathway, with potential deposition on soil and in surface waters.
- Monitoring was conducted prior, during, and after the flaring that included sampling of air, snow, surface water, domestic water supplies, milk, vegetation, soil, and animals.
- EPA has continued to monitor surface water and shallow ground water following the flaring.

EPA sampling near Rulison (2007)

Monitoring: Potential Pathways

Currently:

- The exposure route of concern is gaseous radionuclides (in water vapor) being brought to surface during natural gas production
- Radionuclides in the nuclear chimney are separated from the land surface by more than 8,000 feet of rock
- The rock formation at the depth of the chimney has low permeability. The pores are half-filled with gas and half-filled with liquid

Water and Gas Sampling

Sampling

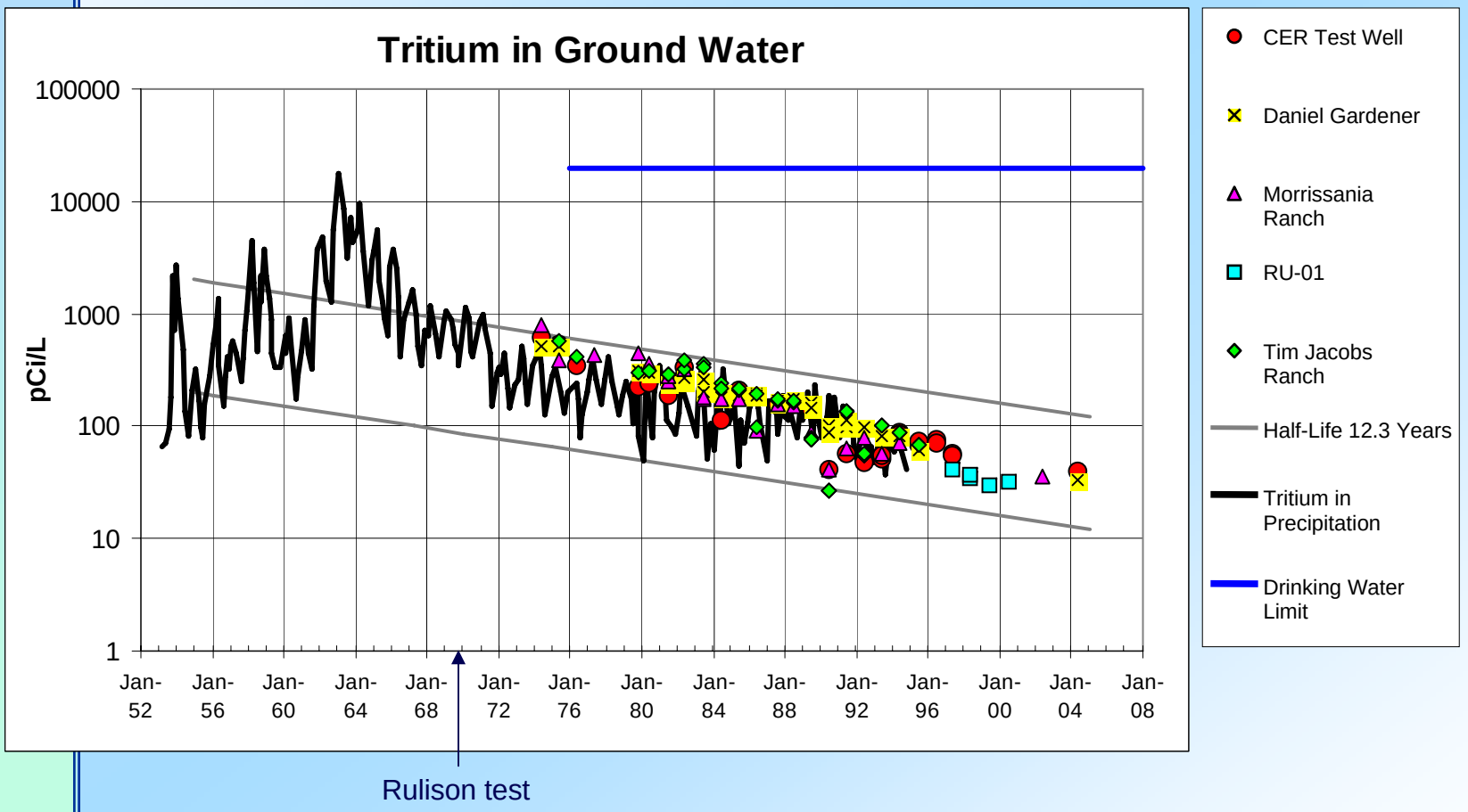
- EPA conducted yearly water sampling from wells, springs, and streams in the area from 1972 to present
  - Analyzed for radionuclides
- DOE has collected gas and liquid samples from gas producing wells in the Rulison field
  - One-time sampling from 12 wells in the vicinity
  - Recently sampled three wells approximately 1 mile from the site

Future Monitoring

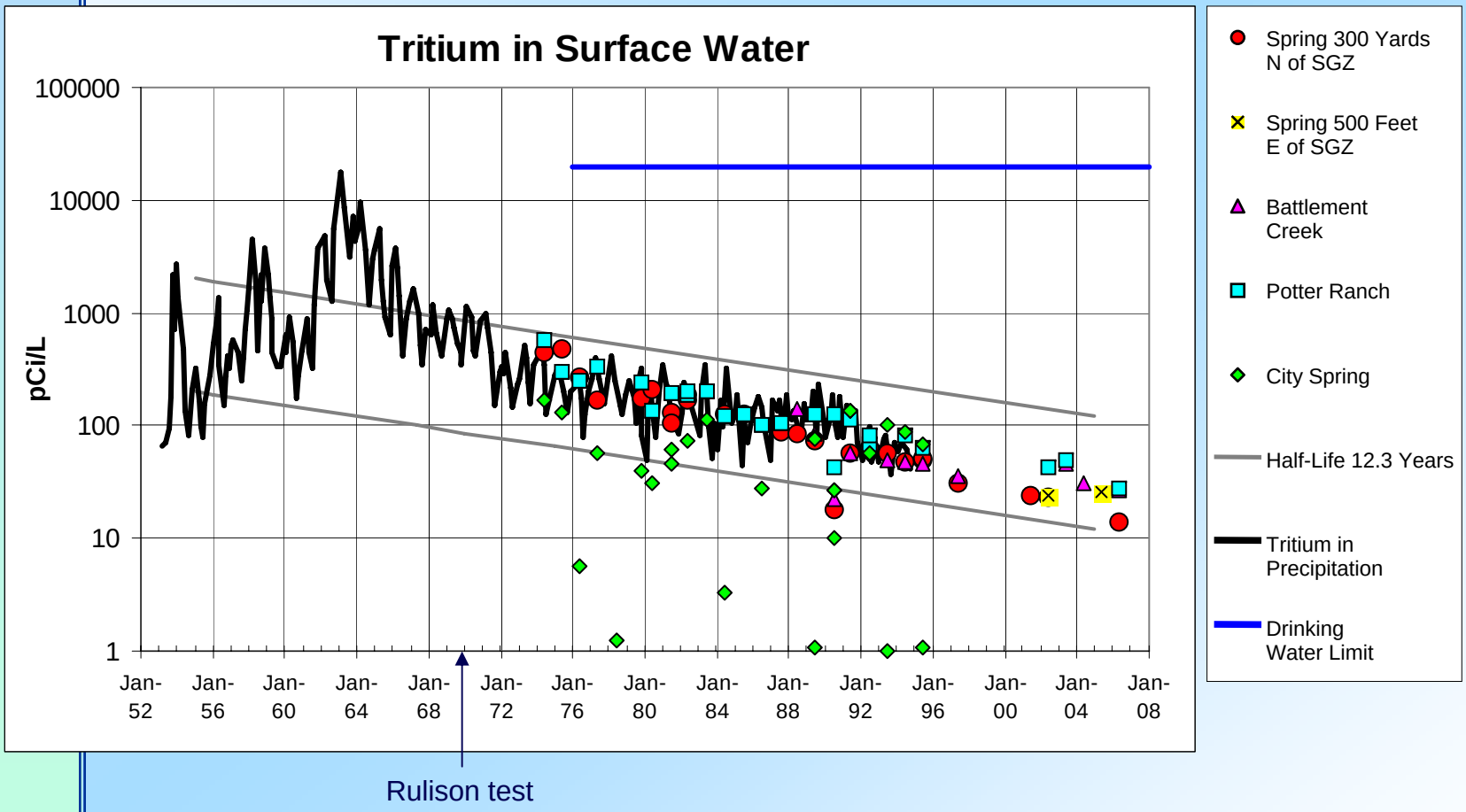
- Long-term management
  - Develop gas sampling plan that includes frequency and locations
  - Continue water sampling from selected locations

Annual Water Sampling Locations

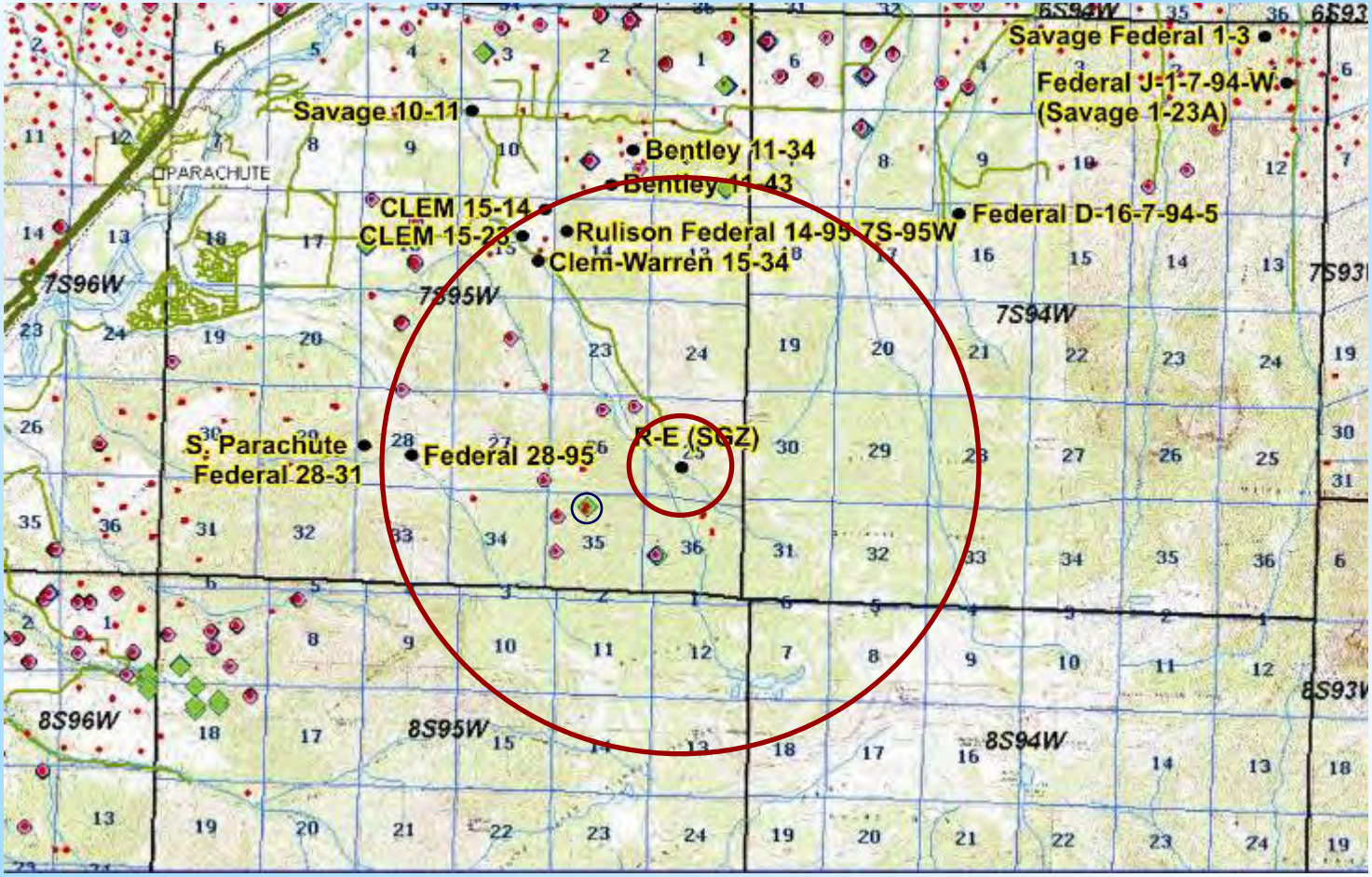
Historical Monitoring Results



Historical Monitoring Results



Gas Sampling Locations



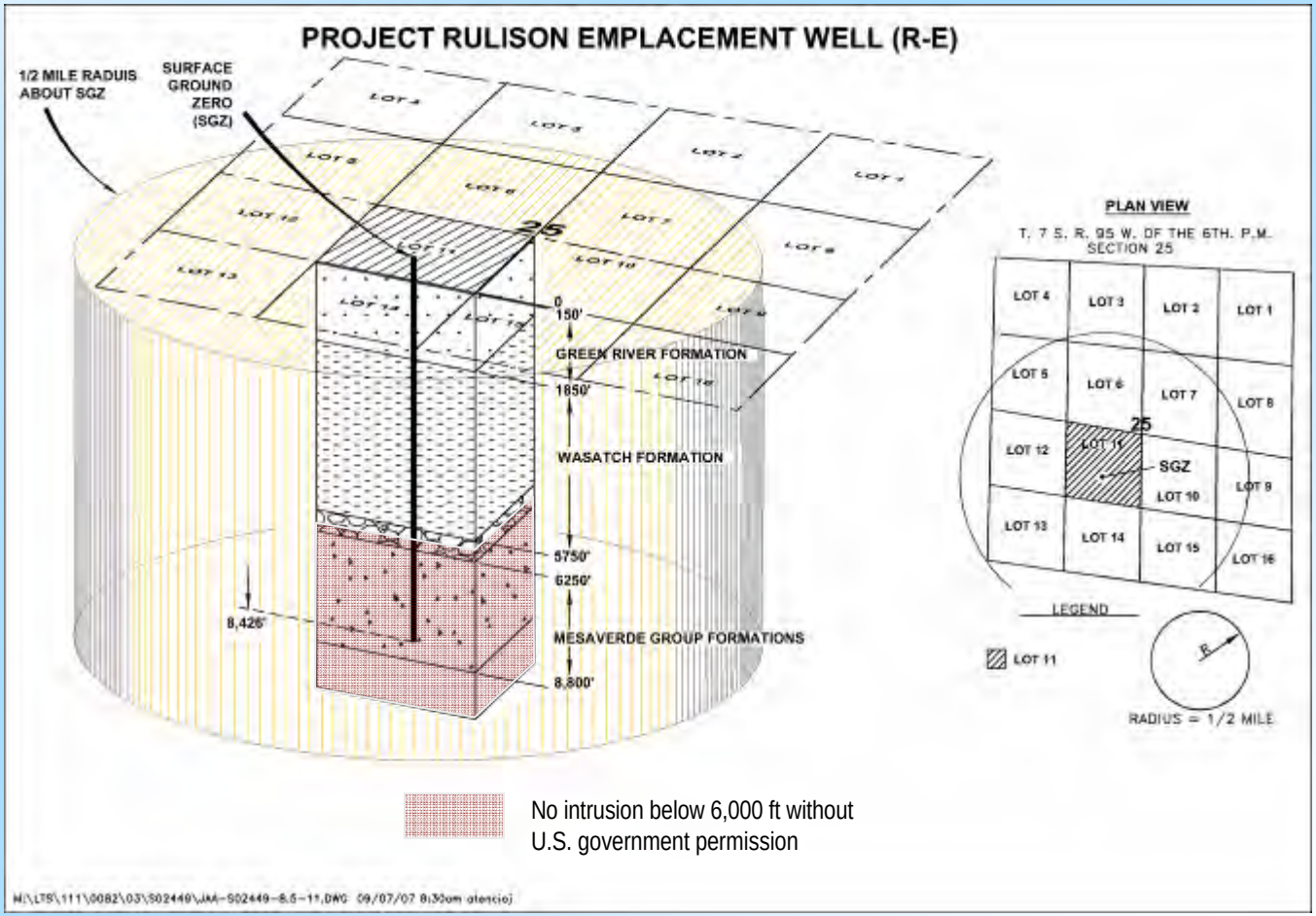
From Colorado Oil and Gas Conservation Commission (COGCC)

Subsurface Investigation

Purpose: achieve a site closure protective of human health and the environment

- No technically feasible way to remove radioactive contamination in nuclear cavity
- Evaluate if existing subsurface restriction is adequately protective
- Establish long-term management program

DOE Drilling Exclusion Boundary and COGCC Hearing Boundary



Modeling as a Tool for Evaluating Rulison Drilling Restriction

- Modeling is a process of organizing information to better understand something
- Models are usually needed when making predictions
- Computer models are used to understand systems that can be described in mathematical ways

Steps of the Modeling Process

1. Define Objectives
2. Develop Conceptual Model
3. Develop Numerical Model
4. Evaluate Uncertainty
5. Evaluate Results
6. Reach Conclusions

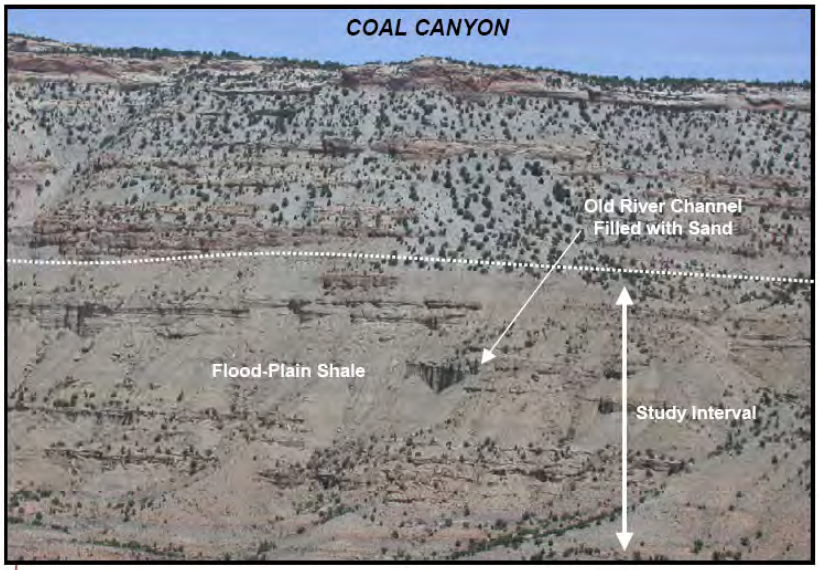
1. Define Objectives

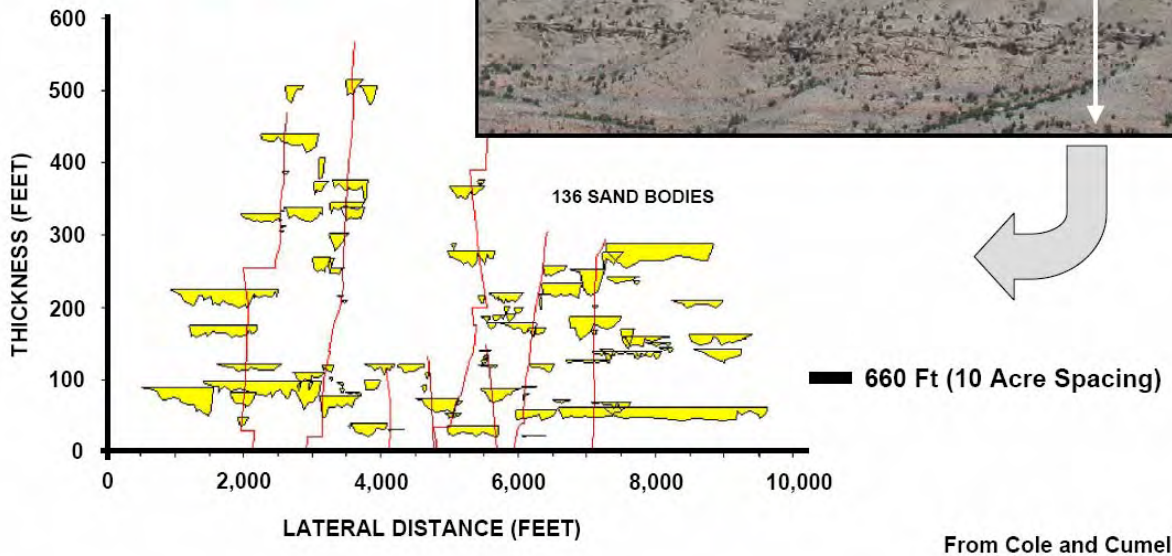
- Calculate the extent of tritium contamination in the subsurface from the time of the Rulison test to present day
- Identify the most susceptible natural gas production well location outside DOE's drilling restriction
- Evaluate tritium migration to that location under a hypothetical gas production scenario

2. Develop Conceptual Model of Reservoir Geometry

The reservoir rocks in the Williams Fork Formation are remnants of ancient river channels filled with sand

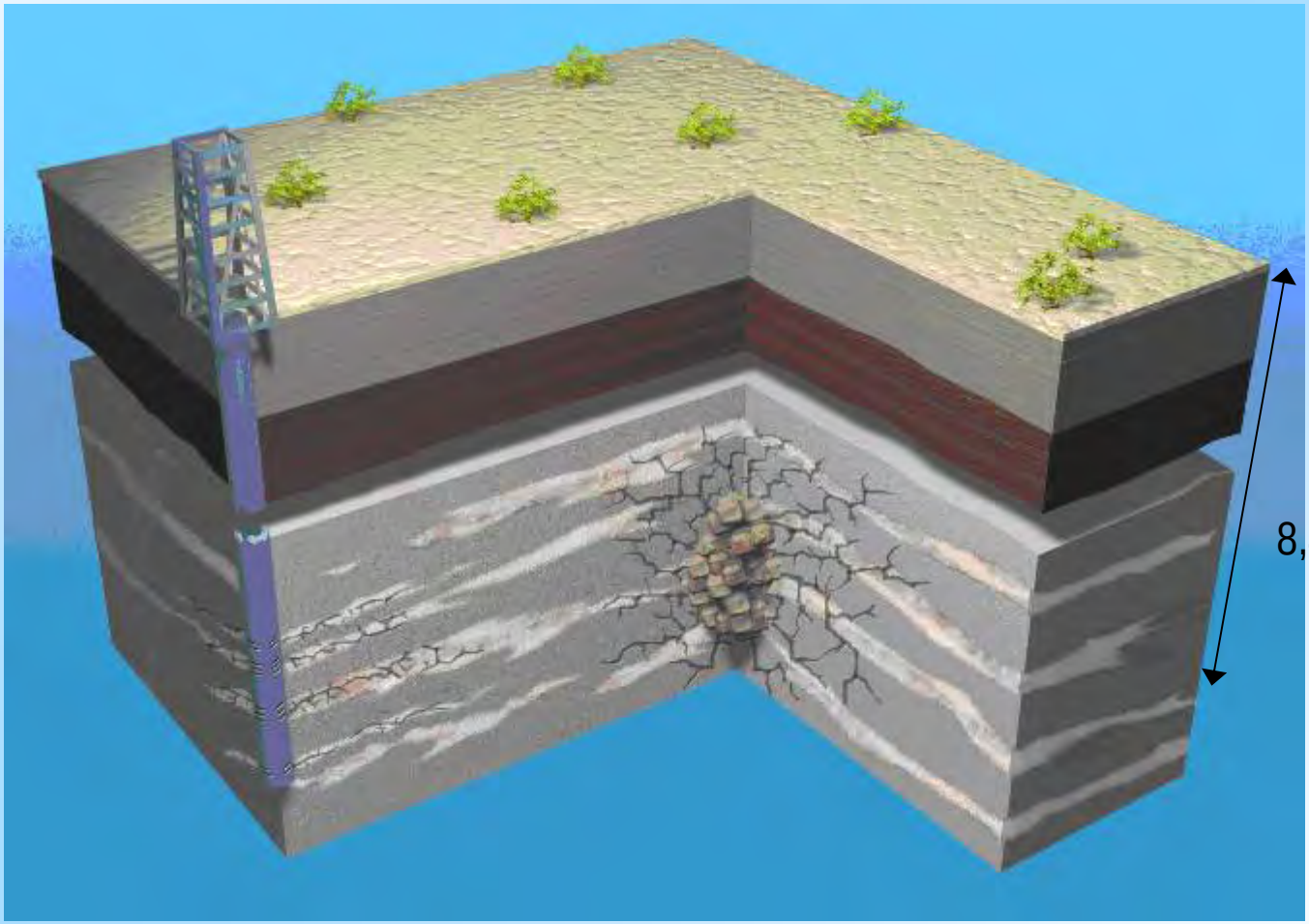
These sand bodies are surrounded by flood-plain shale



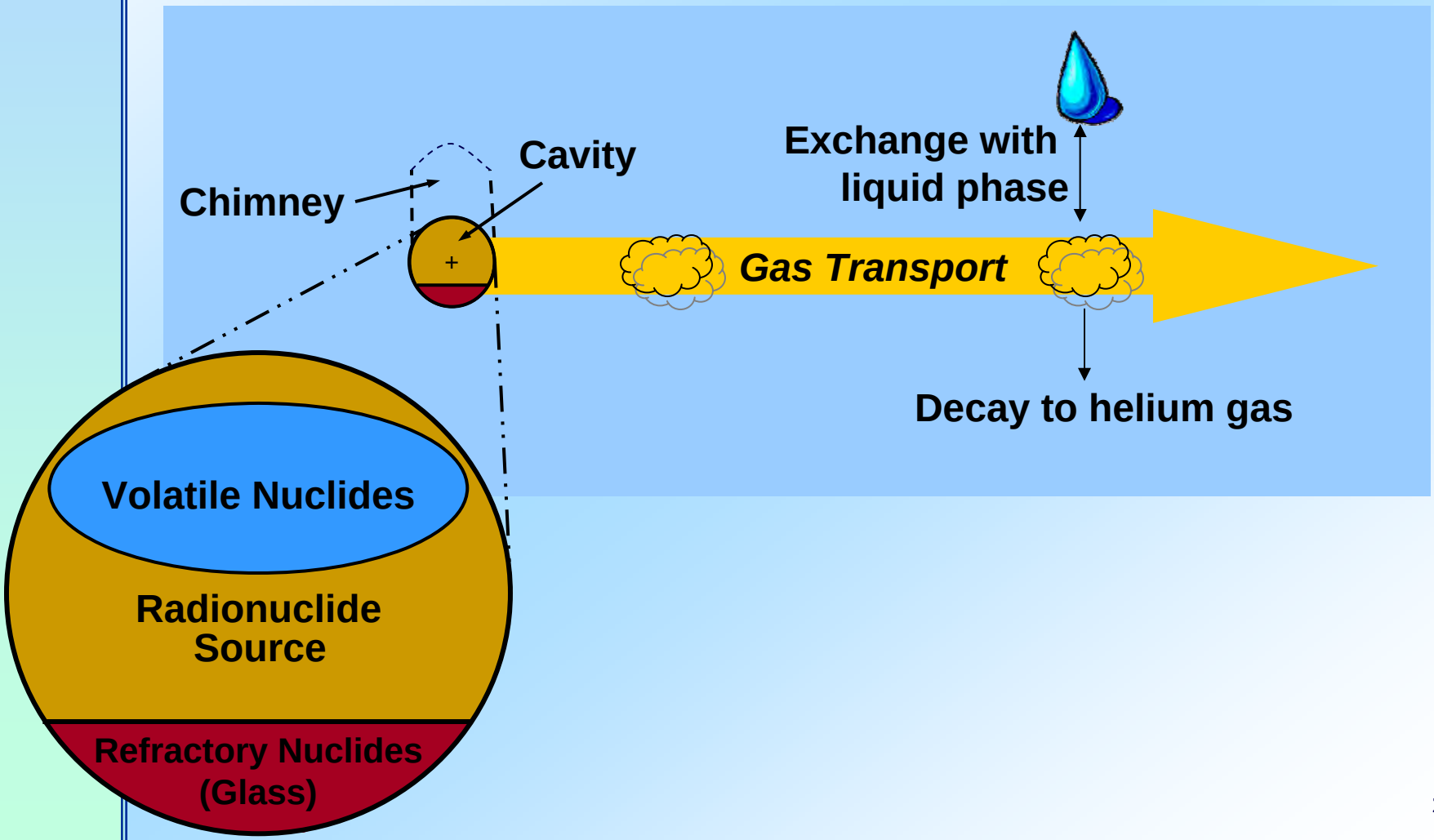


From Cole and Cumella (2005)

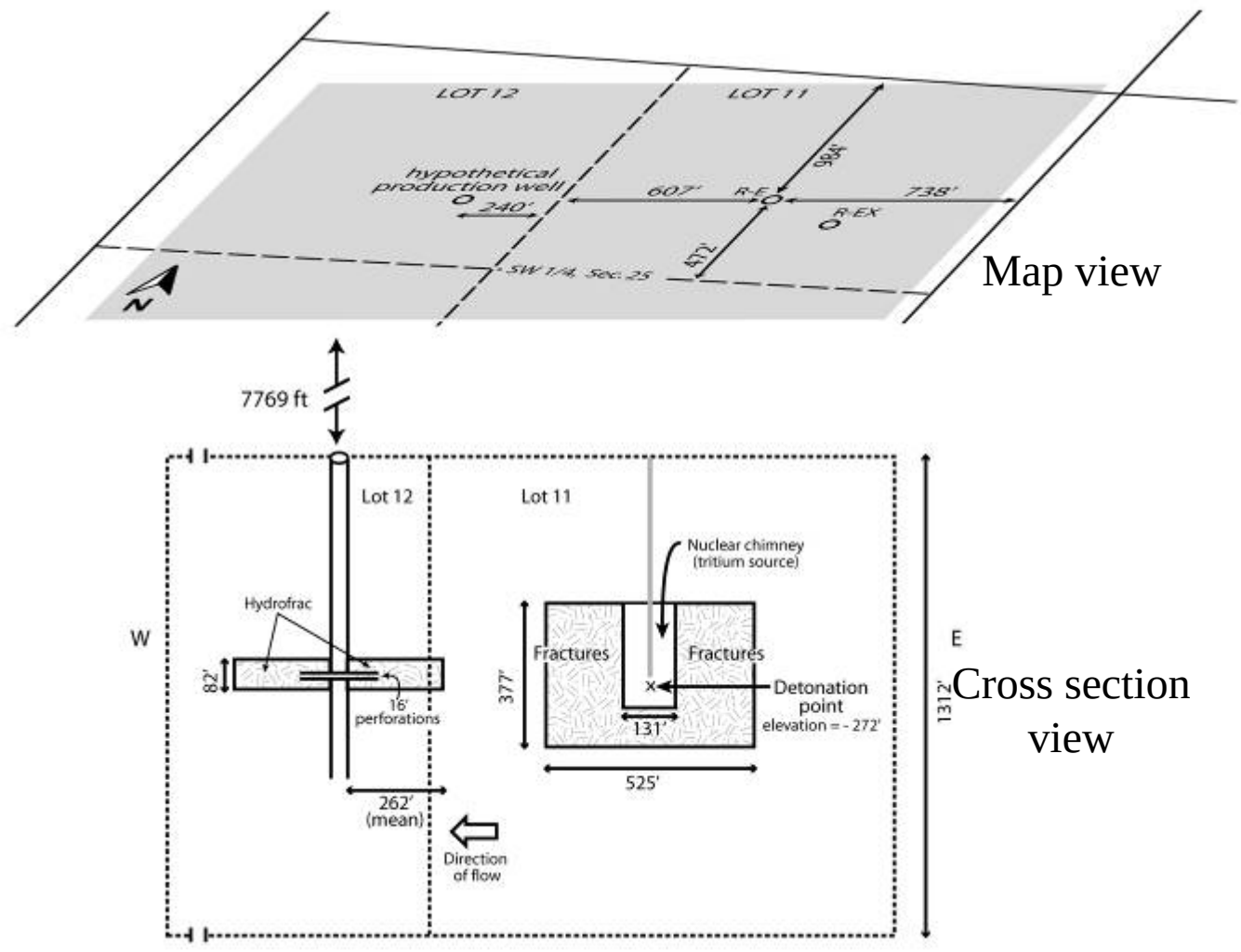
2. Develop Conceptual Flow Model



2. Develop Conceptual Transport Model



3. Develop Numerical Model



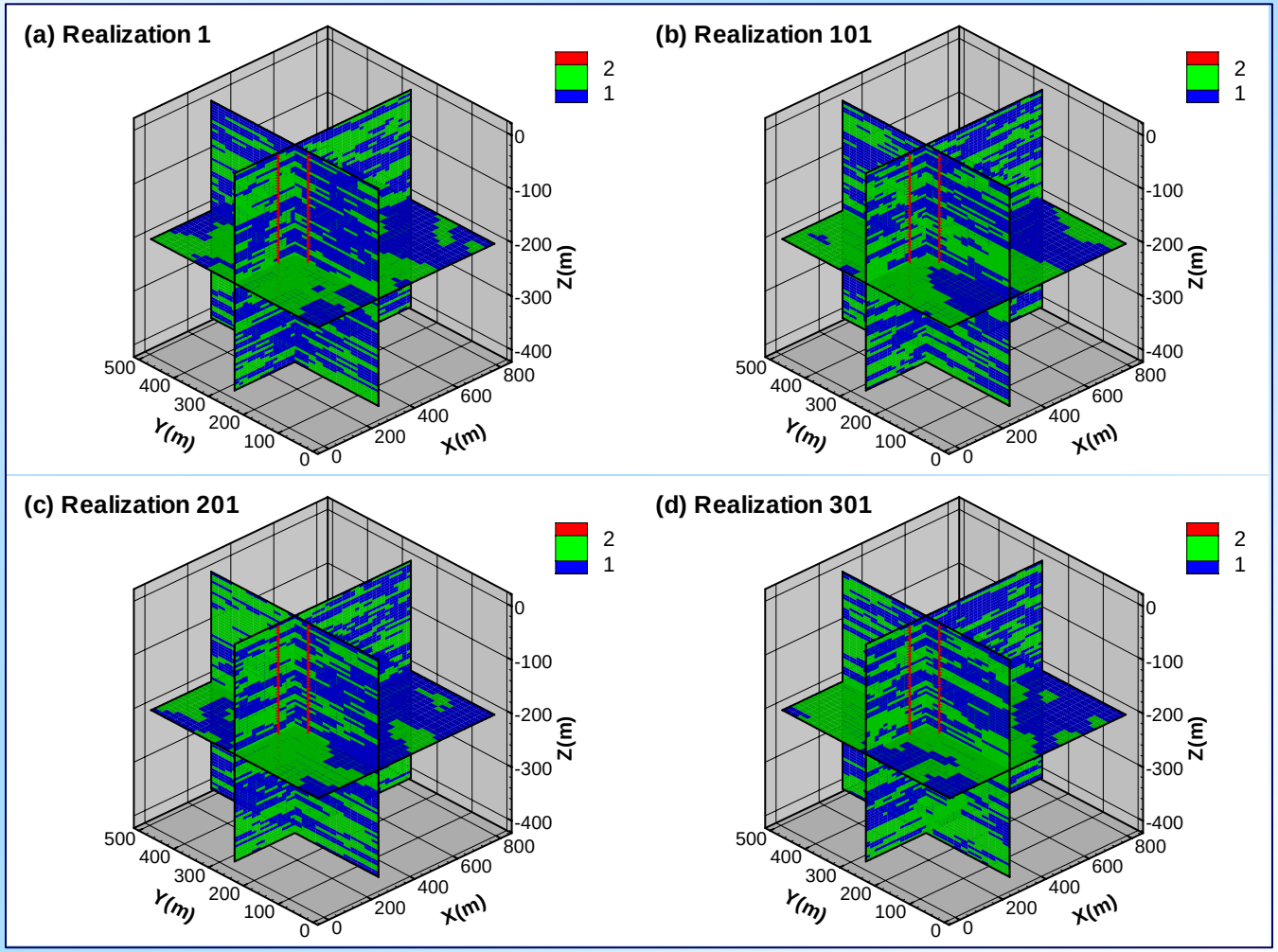
4. Evaluate Uncertainty

- Limited information from the subsurface
- Natural spatial variability

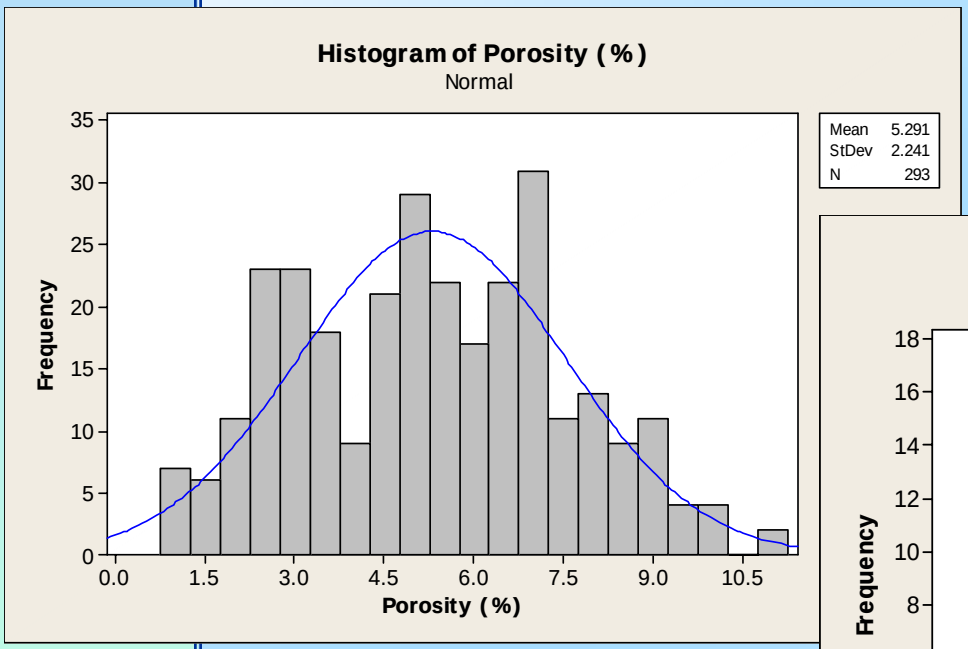
Address uncertainties by:

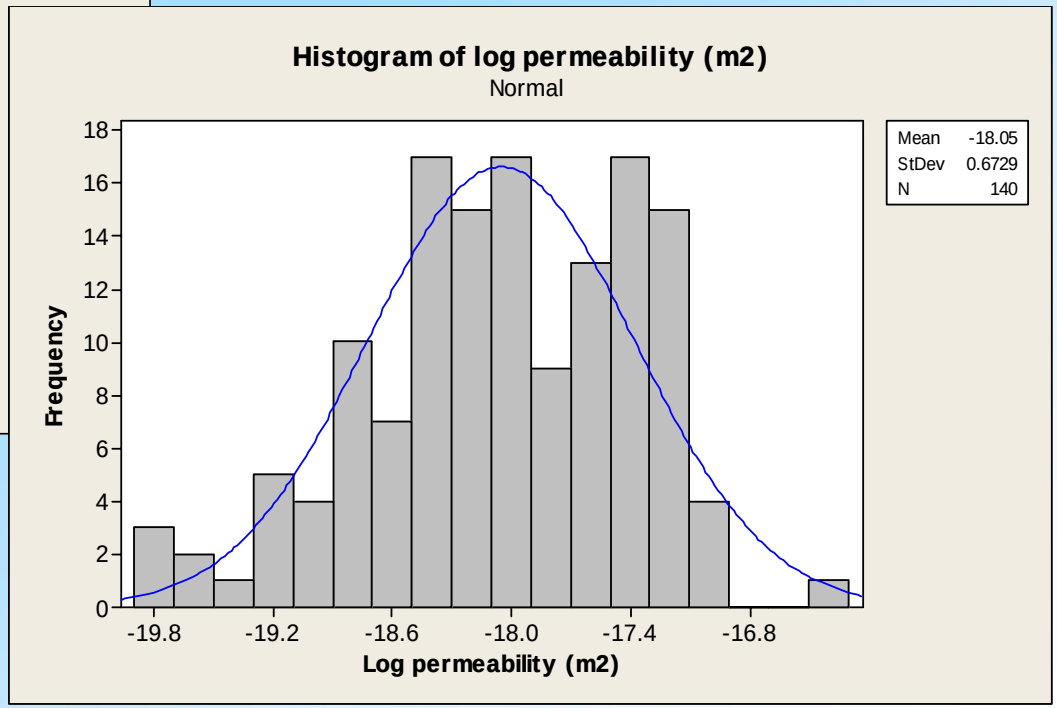
- Using many possible sandstone-shale combinations
- Using range of values

4. Evaluate Uncertainty: Sandstone-Shale Layers



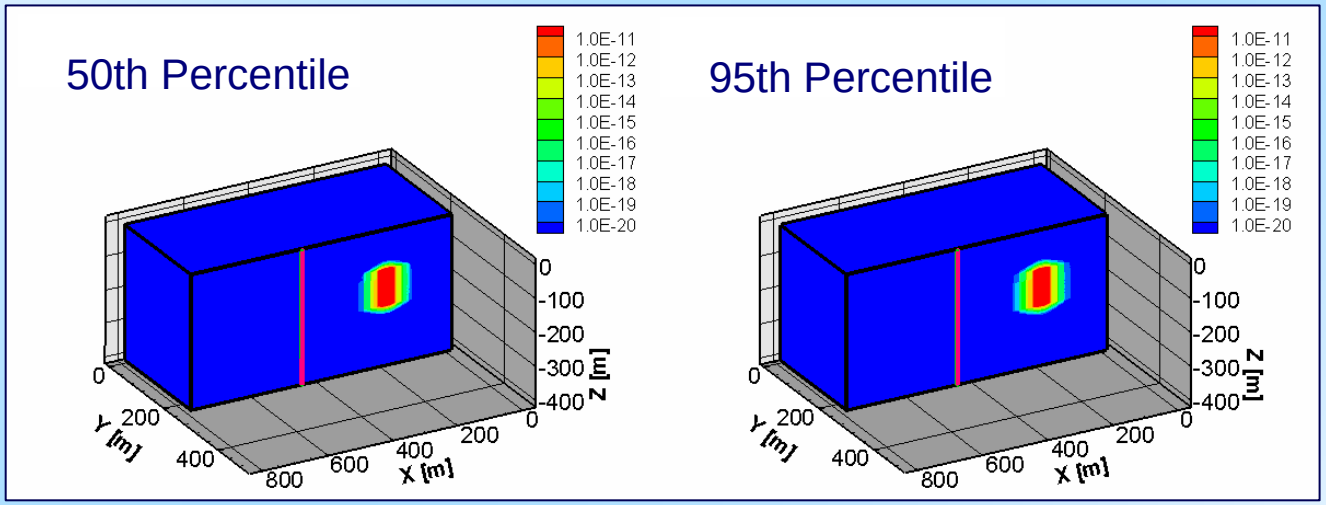
4. Evaluate Uncertainty: Parameter Distributions





5. Evaluate Results

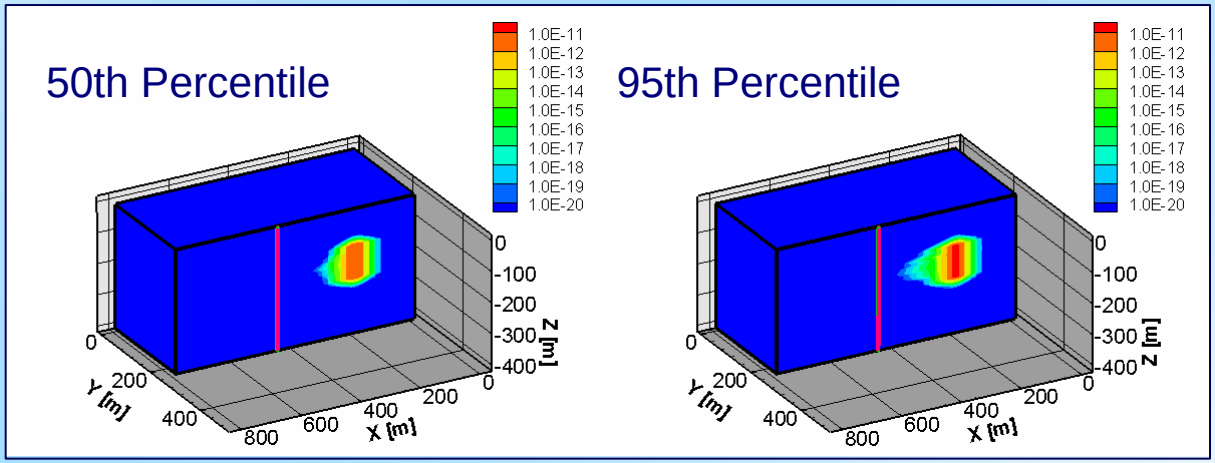
- At present, tritium is estimated to have migrated about 260 feet (80 meters). This is within the zone fractured by the detonation.



Present Day

5. Evaluate Results (continued)

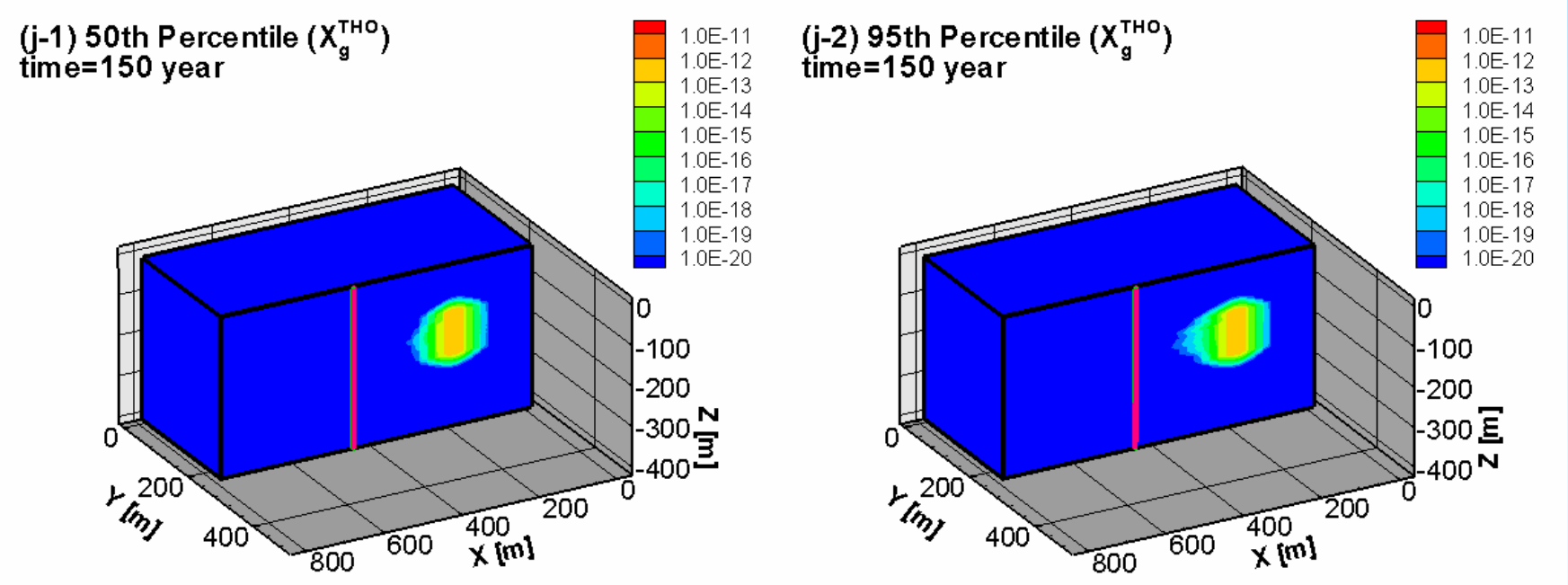
- A hypothetical gas well to the west of the DOE exclusion area, pumping at same depth as the nuclear test, enhances migration in many of the cases. But tritium does not arrive at the gas well in over 95 percent of the simulations.



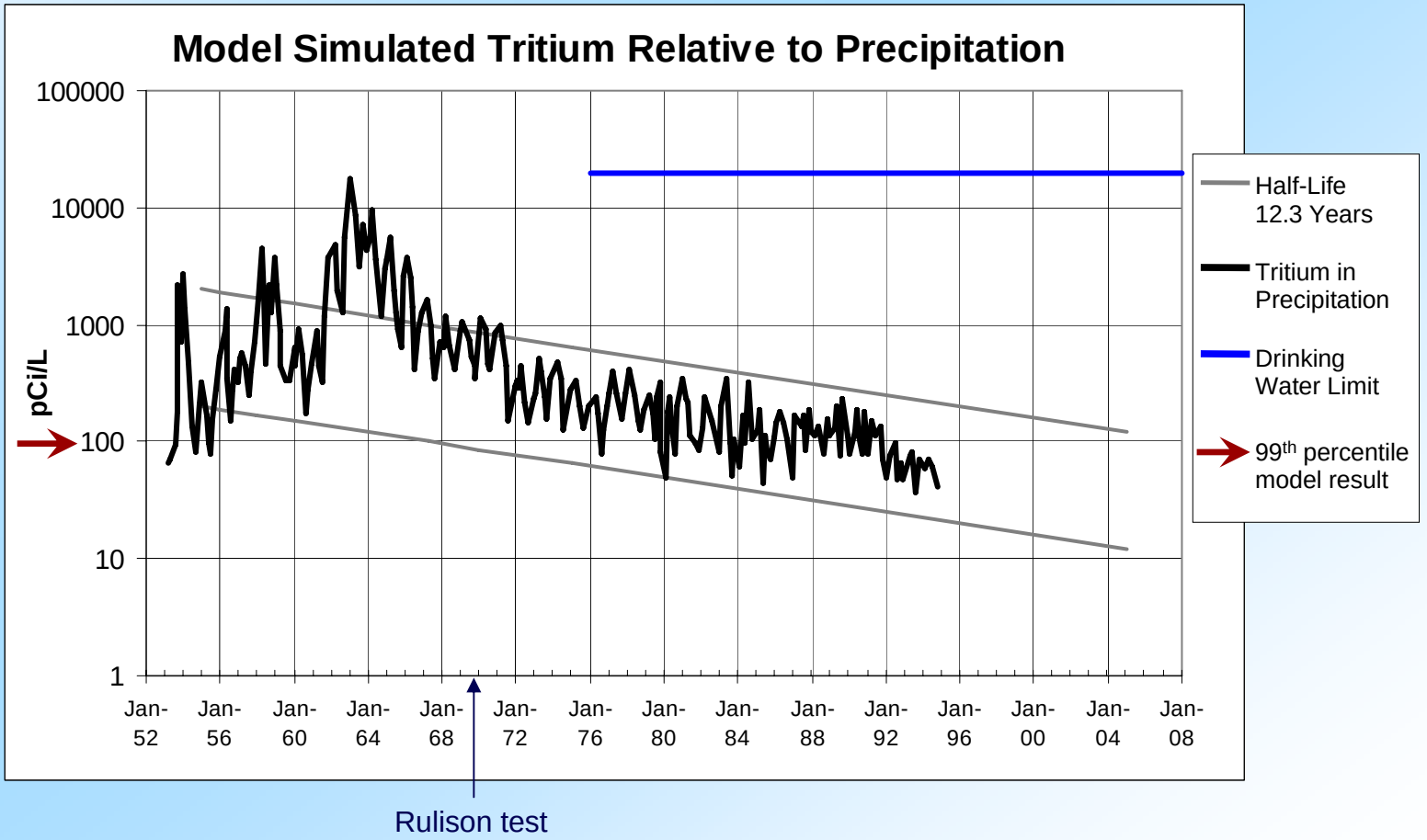
After 30 years of production

- The 95th percentile shows more transport than the 50th percentile

5. Evaluate Results: 82 Years After Production Ceased



5. Evaluate Results: Historical Monitoring



6. Reach Conclusions

- Migration of tritium in absence of nearby gas field production is driven by diffusion, maximum distance estimated to be about 260 feet (80 meters)
- In the presence of gas field production, the most susceptible location is west of the nuclear test, hypothetical production did not result in tritium at pumping well in over 95 percent of model simulations
- Impacts of dilution and mixing during actual gas production and distribution not included, but would further reduce contaminant concentrations

Next Steps

- DOE will address comments from the regulatory agencies about the 2007 modeling report
- DOE will assist the regulatory agencies with recommendations regarding future regulatory boundary limits
- Data from nearby drilling can be used to confirm and update the model if necessary
- Monitoring will be a key aspect of site management; details will be developed with CDPHE and COGCC on the technical approach and protocols

Additional Information

- Office of Legacy Management website:
  http://www.LM.doe.gov
- Rulison Site web page:
  http://www.LM.doe.gov/land/sites/co/rulison/rulison.htm
- Plowshare Program:
  https://www.osti.gov/opennet/reports/plowshar.pdf
  http://www.nv.doe.gov/library/factsheets/DOENV_766.pdf